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**Lyon Inc. -- Detroit, Mich.
Deep Drawn
Ausforming Development
Program
Contract NOw 60-0634 (FBM)
General Report #5
March 31, 1963**



INCORPORATED

ORDNANCE PRODUCTS DIVISION

MANUFACTURERS
OF

CARTRIDGE CASES • BOMBS • ROCKET MOTOR CHAMBERS
AND MISSILE COMPONENTS

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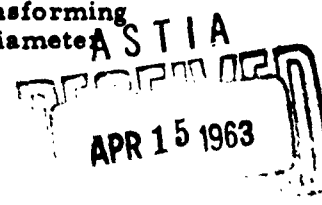
March 31, 1963

Director, Special Projects
Bureau of Naval Weapons
Department of the Navy
Washington 25, D. C.

Attention: Special Projects Office (Code SP-271)

Subject: General Report No. 5 on Deep-drawn Ausforming
Development Program, one-piece 12" diameter
rocket motor chambers

Reference: Contract N0w 60-0634(FBM)
Schedule - Item 3



Gentlemen:

This report summarizes the progress made through
March 31, 1963, on the subject contract. Copies of this general
report are being distributed according to the attached distribution
list for metal parts as specified in the contract.

Sincerely yours,

LYON INCORPORATED

Wayne A. Martin
Wayne A. Martin, Director
Lyon Ord. Res. and Mfg.

Copy No. 19

**LYON INCORPORATED
DETROIT, MICHIGAN**

**General Report No. 5
for the period
through March 31, 1963
on**

**Deep Drawn
Ausforming Development
Program
12 Dia. Rocket Motor Chambers**

Submitted to:

**Bureau of Naval Weapons
Code SP-271
Contract N0w 60-0634(FBM)**

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Contract Objective

The general objective of this contract is to develop and apply the technique of ausforming or working of metastable austenite to deep-drawn, one-piece rocket motor chambers in an effort to achieve a uniaxial yield strength at 0.2% offset of 400,000 psi. An outline of the Scope of Work of the contract is presented in the Appendix to this report.

Abstract

✓ Twenty-five forged billet blocks of 300-M steel have been processed up to the operation just prior to ausforming. Six of these chambers were given the final fabrication operations by cold drawing to provide test cases which can be quenched and tempered in the normal manner. Five of the cases have been hardened and shipped to the U. S. Naval Weapons Plant for testing.

Laboratory studies have been made of the strength and ductility, as measured by a tensile test, of austenite at 1000° F. In addition, the Scientific Laboratory of Ford Motor Company has conducted studies of the ausformed properties of the particular heats of 300-M steel to be used for this program.

Although the program was delayed, due to problems during fabrication of the ausforming die assembly, these problems have been solved and fabrication of the die assembly has been completed. ↗

The immediate future effort on the program will be centered upon installation of the instrumentation, heating systems, and initial die tryout.

Summary of Past EffortDirect Raw Material

Twenty-five forged billet blocks, comprised of four consumable electrode heats, of double vacuum melted 300-M steel were purchased from Universal-Cyclops Steel Corporation. The following identification was assigned to this material.

<u>Quantity of Pieces</u>	<u>Heat Number</u>	<u>Lyon Code Numbers</u>
8	KH-856-K1	AJ-1 through AJ-8 inclusive
8	KH-857-K1	AK-1 through AK-8 inclusive
1	KH-860-K1	AL-1
8	KH-861-K1	AM-1 through AM-8 inclusive

All twenty-five of the forged billet blocks were macro etched and were found to possess satisfactory quality. In addition, tests were made to verify the chemical composition and non-metallic inclusion ratings of the material. These tests revealed that the material was satisfactory for use.

A twelve-foot length of one-inch bar stock from each consumable electrode heat was also purchased for laboratory studies of the ausforming process.

Preliminary Fabrication of Motor Chambers Prior to Ausforming

The initial fabrication step consisted of hot pancaking the twenty-five forged billet blocks in round, flat blanks. After pancaking, these blanks possess radial flow lines which are the most ideal direction for deep-drawing and forming. Pancaking was performed by heating the forged billet block in neutral salt, transferring the block to preheated, flat platens in the press, and upsetting. After upsetting, the parts were buried in vermiculite, slow cooled to 700° F., normalized by heating in neutral salt at 1725° F., and slowly cooled in vermiculite to room temperature. The blanks were then machined to the hot cup blank size of 25.5 inches in diameter by 0.820 inches thick. This required the removal of approximately 0.100 inches of stock from all surfaces.

The machined blanks were then processed through the hot cup operation. Essentially, this operation consists of heating the blank in neutral salts to 1825° F., transferring to the press, and cupping by the use of a preheated punch and die section. Once again, the cups were slow cooled in vermiculite, normalized at 1725° F., and slow cooled in vermiculite to room temperature. In order to provide the optimum condition for subsequent drawing at room temperature, the cups were isothermally annealed to a 100% spheroidized microstructure.

The cases were then processed through four cold draws and a prehead operation with each draw reducing the sidewall approximately 30% with a corresponding increase in length of sidewall. Prior to each cold draw, the cases were coated with phosphate and soap to provide lubrication during the draw. After each draw, the cases were process annealed to recrystallize the cold worked structure and to remove the strains of deformation.

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Six of the motor chambers were then processed through the balance of the press operations which consisted of two more draws and a heading operation. One of these chambers was sectioned for metallurgical analysis and the remaining five chambers were heat treated to provide test chambers representative of the normal quench and temper hardening method. Four of the five hardened chambers were shipped to the U. S. Naval Weapons Plant for testing and evaluation. The remaining hardened chamber will be hydrostatically tested to burst pressure by Lyon Incorporated at the time the ausformed chambers are tested for comparison purposes.

Laboratory StudiesElevated Temperature Tensile Tests

Elevated temperature tensile tests were conducted to determine the strength and ductility of 300-M steel in the austenitic condition at 1000° F. These tests consisted of resistance heating the specimens to 1700° F., cooling rapidly to 1000° F., equalizing at 1000° F., and performing a standard hot tensile test. The results obtained revealed an average yield strength of 17,000 psi and reduction of area of 94%. These data indicate that ample local ductility is available for ironing and that the tonnage requirements for ironing will be considerably below that required for reduction at room temperatures.

Ausformed Properties of 300-M -- Performed and Reported by the Ford Scientific Laboratory

The results of laboratory studies conducted by the Ford Motor Company Scientific Laboratory as part of this program and presented in our General Reports 2 and 3 have indicated that yield strengths in excess of 300,000 psi can be obtained with 300-M steel after ausforming over a temperature range of 950° F. to 1200° F. The reductions used during these tests were 51%, 68%, and 85%. Although the strengths obtained after 85% reduction provided the highest values, the rate of increase in strength after 51% reduction was considerably less. That is, the yield strength obtained after 51% reduction was approximately 310,000 psi whereas the yield strength after 85% reduction was 330,000 psi. These values can be compared to the normal quenched and tempered yield strength of 245,000 psi. In addition, the response to ausforming was found to be independent of the temperature used in the range of

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950° F. to 1200° F. This effect was attributed to simultaneous transformation during deformation which was particularly pronounced at the lower temperatures and higher reductions. Since these data were obtained with unheated tooling, it is possible that a portion of the transformation was not strain induced but resulted from surface chilling of the work.

Special ToolingDesign

The data obtained from the laboratory work by Ford, together with our knowledge of the capabilities of deep-drawing, were considered during the design of the ausforming die assembly. In order to achieve a yield strength in excess of 300,000 psi, and yet avoid excessive tensile loads in the reduced sidewall, the amount of sidewall reduction during ausforming was selected as 50%. Because of the time of contact between the workpiece and the tooling, it was necessary to incorporate in the design a method of internally heating the tooling. The heating method and a description of the ausforming die assembly have been presented in General Report No. 4.

Fabrication

Problems were encountered during the fabrication of the die assembly which resulted in a delay in this program. As reported previously in General Report No. 4, these problems centered upon those components of the die assembly which had been made from AISI H-42 tool steel. This material was selected for use since it possesses the required hardness and strength at the operating temperature of approximately 1000° F. Realizing that the subject die components would be among the largest, if not the largest, forgings fabricated from H-42 steel, considerable effort was spent in informing our fabrication and material vendors of the use and requirements of the forged die components. Despite these precautions, heat treatment of the AISI H-42 steel forgings was unsuccessful due to cracking. The results of metallurgical analyses upon the failed forgings, a summary of which were presented in report No. 4, indicated that a combination of factors relating to hot working and heat treatment techniques were responsible for the difficulties.

Current Status of ProgramSpecial Tooling

At the date of our last report, three of the five AISI H-42 tool steel die components had cracked during final heat treatment. Although nothing could be done to alter the previously performed hot working history of the remaining two details, modifications were made to the hardening technique. The hardening temperature was decreased and the tempering cycle was changed to lower temperatures on the initial double temper. Moreover, the cooling period after the first temper was carefully monitored. As soon as the component cooled to 150° F., it was immediately loaded into a warm furnace (100° F. to 150° F.) and given a second temper at 1050° F. Hardness tests were not made until after the second temper. Prior to hardening, thermocouples were attached to the part to determine actual workpiece temperature during the high heat. Heating rates were controlled throughout the processing to prevent thermal shock and steep temperature gradients in the part.

Despite these precautions, hardening of one of the die details was not successful. Examination of the heading retainer (D-20070-7) after the quench revealed that the bottom surface had been severely overheated in a localized area. Without doubt, this condition had resulted from impringement of air or other oxygen containing gases upon the part due to inadequate sealing of the furnace. Extensive cracking had occurred in and adjacent to the overheated portion of the part. The heat treat source acknowledged responsibility for the cracked part.

The heat treatment of the large punch, E-20070-5, was successful. In this case, the condition of the furnace was verified by processing other

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parts prior to treatment of the punch. After four tempering operations, the hardness of the punch was reduced to 55 Rockwell "C" scale which was within the desired range.

Concurrent with the heat treatment of the last detail, arrangements were made for the replacement of the four cracked components. Specific procedures for hot working practice were established with the forging source. The objective of these procedures was to provide maximum break-up of the ingot carbide distribution and to provide pieces which could be more readily hardened.

The four replacement forgings were received and were submitted for hardening and finish machining. Because of the lack of success with the original forgings, the replacement forgings were processed with great care during machining and hardening. All four components were successfully heat treated to a Rockwell "C" hardness of 55 which was within the desired range. After hardening, the parts were finish machined to the requirements of the engineering drawing. All of the components of the die assembly are now in-house and have been dimensionally inspected.

Future Effort

Future effort on this program will include:

1. Connection of the temperature measuring instrumentation and the tooling heating systems.
2. Installation of the insulators.
3. Installation of the die assembly in the press and initial tryout.

Appendix

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Scope of Work

The Scope of Work as outlined in the referenced contract is as follows:

Conduct an ausforming program to develop and apply the technique of hot-working in the austenitic phase on deep-drawn, one-piece 11.65" diameter by approximately 36" long rocket motor chambers. This development is to include the forward dome as well as the cylindrical sidewall in an effort to achieve a uniaxial 0.2% offset yield strength level of 400,000 psi. The steel to be used in this development will be double vacuum melted steel wherein the first melt is vacuum induction and the second is consumable electrode vacuum remelt. The type of steel to be used shall be Tricent (M-300). This work shall include the following effort:

- a. Approximately twenty-four forged billet blocks will be hot pancaked and deep drawn through the cup, 1st, 2nd, 3rd, and 4th draw operations including the pre-heading operation utilizing Asroc tooling.
- b. After the prehead operation, the motor chambers will be given a sub-critical anneal to relieve the cold work strains. The chambers will be used from this stage to develop the operation of hot working in the austenitic phase by austenizing the steel followed by the plastic deformation at an isothermal, subcritical temperature. The percentage of reduction to be tried in the operation of hot working in the austenitic phase will be that mutually agreed on by the Special Projects Office and Lyon Incorporated.

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- c. After the tooling is developed for the final hot draw operation (hot working in the austenitic phase), motor chambers will be hydrostatically tested to burst pressure utilizing electrical resistance strain gauges to determine the yield and burst pressures.
- d. Fracture toughness data shall be supplied from specimens heat treated with the chambers. The fracture toughness test shall be conducted under the supervision and guidance of the Naval Research Laboratory.
- e. After Item (c) is completed and the results submitted to the Special Projects Office, four (4) motor chambers will be hot worked in the austenitic phase and shipped to the Naval Weapons Plant for complete evaluation.
- f. Four (4) similar non-hot-worked chambers will also be supplied to the Naval Weapons Plant as a comparison of strength and performance values.

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